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COSTS OF JUNIPER CONTROL: BULLDOZING vs. BURNING INDIVIDUAL TREES

by

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in cooperation with

FARM ECONOMICS RESEARCH DIVISION
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The Rocky Mountain Forest and Range Experiment Station maintains central headquarters in cooperation with Colorado State University at Fort Collins.

COSTS OF JUNIPER CONTROL: BULLDOZING vs. BURNING INDIVIDUAL TREES

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Cost is important in selecting a method for controlling juniper. A study of costs by two methods is reported here: (1) Burning individual trees, with either 1- or 2-man crews, and (2) bulldozing. Data from the study can be used to predict the relative cost of control by these methods.

The study was based on records taken from control operations in Arizona. These records give the average time required to treat trees of various sizes and to move the equipment to trees at various distances.

The primary variables that determine costs are the size of trees, the number of trees per acre, and the hourly charges for equipment and labor. Bulldozing costs also may be affected by type of soil, soil moisture, presence of surface rock, terrain, experience of operator, size of tractor, species of juniper, and the shape and branching of trees. Costs for burning may also vary with terrain, experience of operator, wind, temperature, humidity, type and pressure of fuel, and tree form. This study was limited to variations due to size and number of trees; other variables were not included.

1/ Agricultural Economist, Farm Economics Research Division, Agricultural Research Service; and Range Conservationist, Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, respectively. This material is a preliminary report of findings from broader studies conducted by the two agencies. The cover sketch was prepared by Barton Wright, Museum of Northern Arizona, Flagstaff, Arizona.

METHODS TESTED

Bulldozers used were 100-125 drawbar-horsepower machines with "hula-dozer" equipment: hinged pusher bars and hydraulic tilting attachments on the blade (fig. 1). The bulldozers were operated in a gear rated at 2.2 miles per hour. The pusher bar was used to tip the trees, and the corner of the dozer blade was used to lift them out of the ground. Usually the trees were removed in one forward motion.

Figure 1.--"Hula-dozer."

Burning was done with a propane torch (fig. 2). In the 1-man operation, a small, wheel tractor was equipped with a hand clutch that permitted moving the equipment without mounting the tractor. In sparse stands, the operator sometimes rode the tractor and burned isolated trees without dismounting. The tractor towed a trailer-mounted 300-gallon propane tank. In the 2-man operation, a tank of the same size was mounted on a pickup truck; 1 man drove full time. Both units used an 8-foot torch. The torch nozzles had two 0.0935-inch orifices (drill size 42), and a smaller orifice for a pilot flame. The trailer-mounted tank had a 50-foot hose to the torch; the pickup-mounted tank had a 25-foot hose. Operating

Figure 2. --Propane torch.

pressure of the propane tanks was 110-125 pounds per square inch. The operator pointed the torch at the base of the tree crown, then triggered a blast of ignited propane until most of the crown flared briefly. The limited grass between trees made fire-control measures unnecessary.

Both bulldozing and burning resulted in a 95- to 99-percent reduction in live tree crown. Bulldozed trees with roots remaining in the ground or burned trees that are not completely defoliated may require one or more seasons to die. A torch operator has better visibility than a bulldozer operator and is less likely to miss small trees.

STUDY CONDITIONS

TERRAIN AND WEATHER CONDITIONS

All measurements were made on moderate slopes and heavy clay-loam soils. Occasional malpais rock outcrops slowed the movement of all equipment. During bulldozing, the subsoil was dry, and the surface soil was moist; however, no traction was lost.

During the individual tree burning, temperatures ranged from 67° to 92° F., and relative humidity varied from 5 to 65 percent, but variations within these limits had no apparent effect on burning time. Average wind speeds were 2 to 12 miles per hour. Burning was faster when there was no wind. When winds averaged 12 miles per hour, the flame burned through the bases of the trees without igniting the tops.

Fifteen trees were sampled on each of 3 days to determine the leaf and twig moisture. Moisture content of the samples varied from 31 to 70 percent (based on ovendry weight), but this variation had no appreciable effect on time needed to burn the trees.

EXPERIENCE OF OPERATORS

Two bulldozing and two burning operations were observed. One bulldozer operator had more than 2 years' experience in clearing juniper with a hula-dozer. The other had had considerable experience with heavy tractors, but had used a hula-dozer for only 1 month. One torch operator had burned juniper for nearly 2 years, and the other had about 4 months' experience. The difference in experience of the operators did not cause appreciable differences in treatment cost.

SPECIES OF JUNIPER AND STAND CHARACTERISTICS

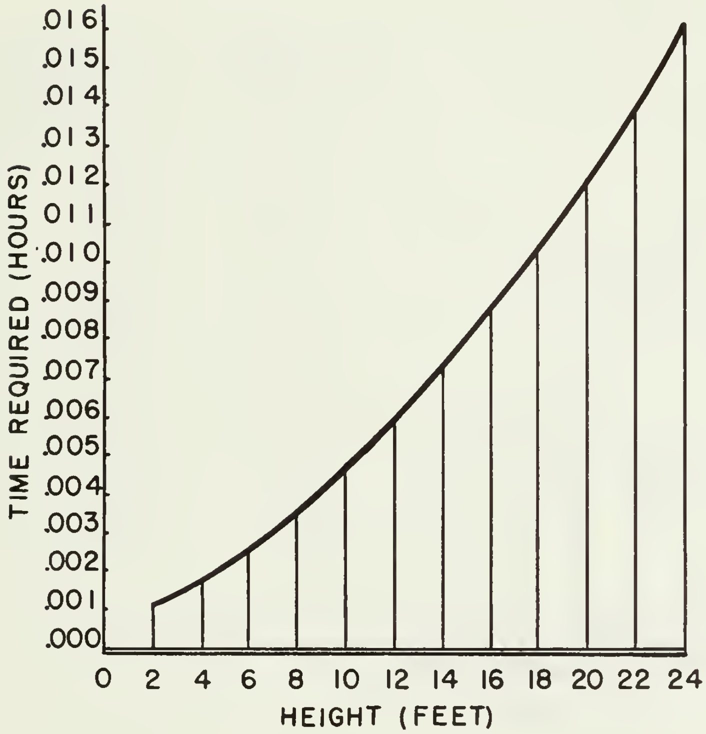
The study areas included pure and mixed stands of one-seed juniper (*Juniperus monosperma*) and Utah juniper (*J. osteosperma*). Probably the results are not applicable to alligator juniper (*J. deppeana*) and pinyon (*Pinus edulis*). The costs may be similar to those for the species studied, but burned alligator juniper will sprout vigorously. Even bulldozing may not kill alligator junipers if stumps are not completely removed from the ground. Bulldozing costs will probably be lower for pinyon than for the species studied. Propane burning of pinyon was not observed.

The study was made in mixed-aged stands. Tree heights ranged from 1 to 30 feet. There were sufficient small and large trees to determine the effect of height on treatment times. Tree spacing varied sufficiently to permit analysis of the travel time between trees.

RESULTS OF TESTS

BURNING TIME

More time was required to burn large trees than small trees (fig. 3). Burning time for individual trees was the same for both the 1- and 2-man operations.

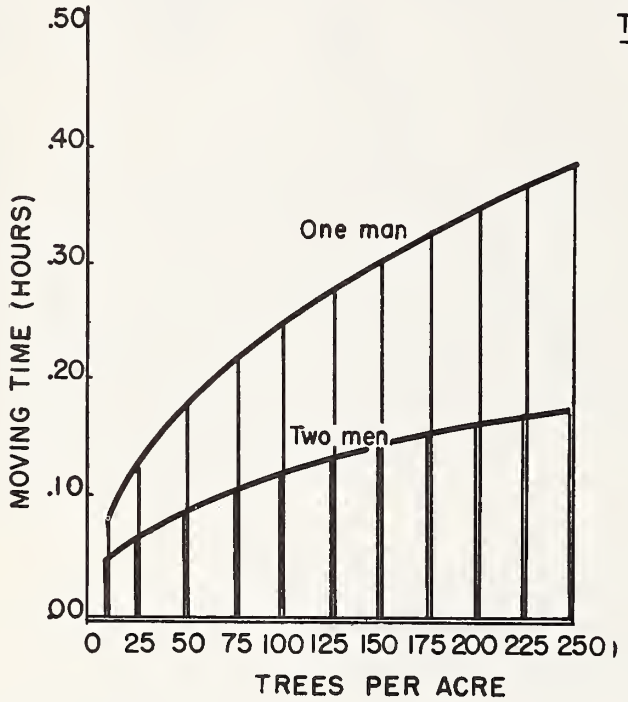


Tree Height Feet	Time Required Hours
2	.0011
4	.0017
6	.0026
8	.0036
10	.0047
12	.0059
14	.0073
16	.0088
18	.0104
20	.0122
22	.0141
24	.0161

Figure 3. --Time required for burning individual juniper trees of various heights with a propane torch. Results are based on 645 trees burned June 6-7 and July 28, 1957.

The estimating equation is $\hat{Y} = 0.0303 + 0.015X + 0.001X^2$ where $\hat{Y}$ is time in minutes and X is the tree height in feet. The curvilinearity of regression is highly significant. The correlation coefficient is 0.780.

Total travel time per acre increased with closer spacing of trees (fig. 4) because the total distance traveled to reach all trees was greater than in open stands. The time measurements do not include rest periods, refueling, or other nonproductive stops. With the 1-man operation, the torch operator had to stop burning to move the equipment. In the 2-man operation, less time was lost in moving, as 1 man drove full time. Travel time of the 2-man crew might have been less if a 50-foot instead of a 25-foot hose had been used.

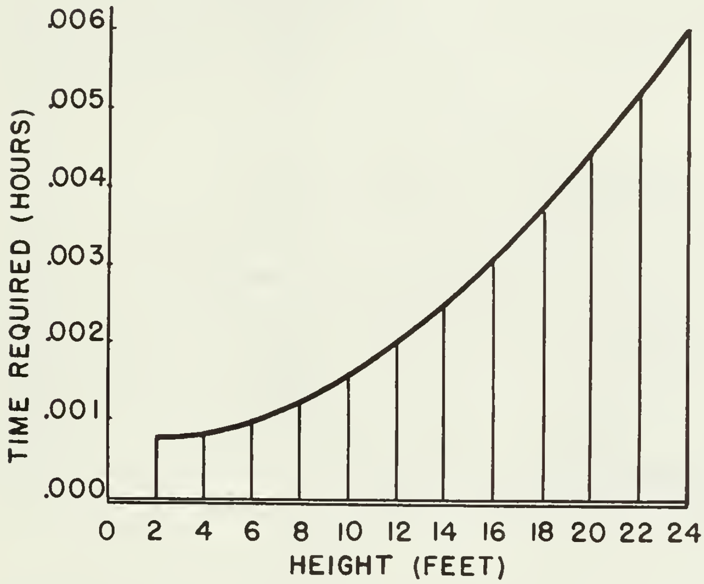


Trees per acre	Time per acre	
Number	One man	Two men
	Hours	
10	.077	.036
25	.124	.057
50	.172	.080
75	.211	.097
100	.244	.113
125	.273	.126
150	.298	.137
175	.323	.149
200	.346	.160
225	.365	.168
250	.384	.178

Figure 4. --Moving time per acre for burning trees individually with 1- and 2-man crews. Results are based on 410 moves recorded concurrently with data in figure 3.

The estimating equations are $\hat{Y} = 0.1940X$ (2 men) and $\hat{Y} = 0.4204X$ (1 man), where X is the distance between trees in feet, and $\hat{Y}$ is the time in seconds. The correlation coefficients were 0.778 and 0.679, respectively. Distance between trees has been converted to total distance traveled for the various number of trees per acre, assuming uniform distribution of individual trees.

Time required to push tall trees was greater than for small trees (fig. 5). There was considerable variation in the time required to remove large trees. Some were uprooted with one forward operation in less than 10 seconds, while others of the same height required 2 to 5 times as long. The size of the root system, position of large lateral roots with respect to the bulldozer blade, and brittleness of the roots and trunk contributed to this variation.

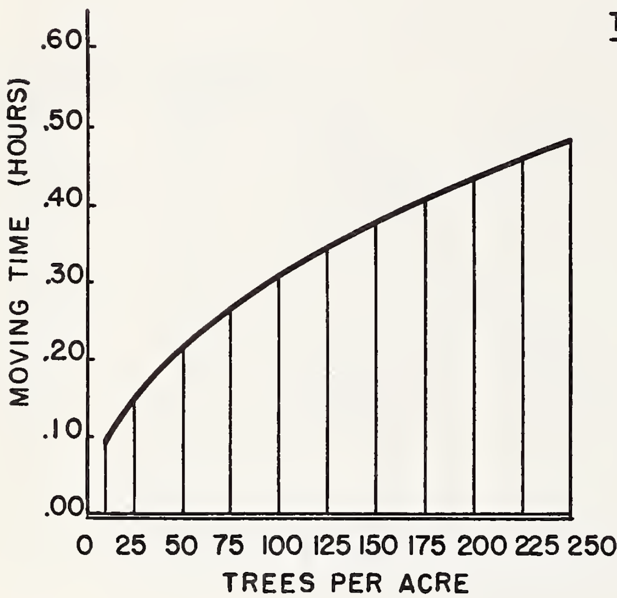


Tree Height Feet	Time Required Hours
2	.0007
4	.0008
6	.0010
8	.0012
10	.0016
12	.0020
14	.0025
16	.0030
18	.0037
20	.0044
22	.0052
24	.0061

Figure 5. --Time required for bulldozing individual juniper trees of various heights. Results are based on 268 trees bulldozed August 20 and October 9, 1957.

The estimating equation is $\hat{Y} = 0.041 - 0.00053X + 0.00058X^2$, where $\hat{Y}$ is time in minutes and X is the tree height in feet. The curvilinearity of regression is highly significant. The correlation coefficient is 0.640.

More time per acre was required to move the bulldozer between trees in the more dense stands because of the greater total distance (fig. 6). Nonproductive time was not included.



Trees per acre	Time per acre
Number	Hours
10	.097
25	.156
50	.216
75	.264
100	.306
125	.342
150	.373
175	.405
200	.433
225	.458
250	.483

Figure 6. --Moving time per acre for bulldozing trees individually. Results are based on 712 moves recorded concurrently with data in figure 5.

The estimating equation is $\hat{Y} = 0.5268\,X$ where X is the distance between trees in feet, and $\hat{Y}$ is time in seconds. The correlation coefficient is 0.845. Conversions to total time per acre were made as described in figure 4.

PREDICTING COSTS FROM RESULTS OF STUDY

Costs for bulldozing and individual-tree burning on a proposed juniper control job can be predicted if the type of equipment studied is available. The following information is needed:

a. Number of trees per acre by height classes and time estimates for burning, bulldozing, and moving from tree to tree to determine the average time required to treat each acre.

b. Expected equipment and labor costs for the job to determine cost per acre for treatment time and moving time.

AN EXAMPLE USING THE 2-MAN BURNING METHOD

A typical 50-tree-per-acre stand to be controlled by the 2-man burning method will be used as an example.

Time Needed to Treat Each Acre

An estimate of the size and number of trees in the stand is needed to estimate burning or bulldozing time and costs. Probably ten 1-acre plots located at random in the area to be treated will be adequate. Additional plots may be required if there is much variation in tree sizes and numbers. Each tree in the plots should be listed by height to show the number of trees per acre by height classes. The completed list may be similar to the one shown in table 1.

The time estimates presented in figures 3, 4, 5, and 6 can be used to predict the time required for each step of the job, provided the equipment is of the size and type described here. In this example, the time required to burn a tree of each height class has been read from figure 3 and entered in table 1. This figure has been multiplied by the number of trees in each height class and the products added to get the total time estimated for actual burning. The time needed for moving from tree to tree with the 2-man burning method in a 50-tree-per-acre stand (fig. 4) has been entered at the bottom of table 1.

Table 1.--Calculating time needed to treat a 50-tree-per-acre stand of juniper with the 2-man burning method

Tree height class (feet)	Trees/acre (from sample plots)	Time required to burn each tree (from fig. 3)	No. hours x No. trees
	No.	Hours	Hours
2	8	0.0011	0.0088
4	9	.0017	.0153
6	8	.0026	.0208
8	7	.0036	.0252
10	5	.0047	.0235
12	4	.0059	.0236
14	3	.0073	.0219
16	2	.0088	.0176
18	1	.0104	.0104
20	1	.0122	.0122
22	1	.0141	.0141
24	1	.0161	.0161
Total No. trees	50		
Total hours per acre for burning			.2095
Total hours per acre for travel (from fig. 4)			.0800

Cost of Treatment Time and Moving Time

Current local rates for each item of equipment and labor should be used to estimate costs for each planned project. The rates used as examples in this report were developed from 1958 operations, and may be different from the actual costs on other jobs. Ranchers may have equipment or family labor that could be employed effectively in juniper control. If so, only direct cash costs such as fuel, oil, repair, and maintenance of equipment may have to be included in the estimates. Fixed or overhead costs, such as taxes and depreciation of equipment, have to be met anyway.

Federal agencies will use contract rates or equipment-pool rental rates. They may also have costs for supervision and planning and, in some instances, fire protection.

Some of the time that must be paid for on a job will not be productive; that is, it will not be used in treating trees or moving from one tree to the next. For instance, the daily travel to and from the project area will reduce the productive time. Extra time may be required to obtain fuel. Since the time estimates from figures 3, 4, 5, and 6 make no allowance for such nonproductive time, rates paid on a total-time basis must be adjusted to a productive-time basis.

In this study only about 80 percent of the working day was spent in burning juniper or in traveling to the next tree. The rest of the time was spent in servicing and refueling, deadheading, and resting. If the cost per hour for a pickup, tank, torch, and 2 men's labor was \$3.37, the rate per productive hour would be \$3.37 ÷ .80 = \$4.21.

Nearly all of the propane was used for actually burning trees, so no correction had to be made in propane costs. The torch equipment used about 20.5 gallons of propane per hour. At \$0.16 per gallon this would be \$3.28 per hour for propane. Thus the total cost per hour for actual burning time estimated from figure 3 would be \$4.21 for equipment and labor plus \$3.28 for propane, a total of \$7.49 per hour. For time spent moving between trees, estimated from figure 4, only the \$4.21 for equipment and labor would be used.

The cost per hour for each part of the job is multiplied by the number of hours per acre needed for that part of the job. The parts are then added together to get the total cost per acre.

Moving time: 0.080 hour per acre x \$4.21 per hour	=	\$0.34 per acre
Burning time: 0.2095 hour per acre x \$7.49 per hour	=	1.57 per acre
Total cost		\$1.91 per acre

OTHER EXAMPLES

The stand used in the above example has been entered in table 2 as stand 1a. Examples of stands of small trees with 100 and 150 trees per acre have been entered as stands 1b and 1c. Large-tree stands of 50, 100, and 150 trees per acre are included as 2a, 2b, and 2c.

Table 2. --Hypothetical numbers and heights of juniper trees for use in sample problems

Tree height class (feet)	Hypothetical stands: Predominantly small trees			Predominantly large trees		
	1a	1b	1c	2a	2b	2c
	No. trees per acre					
2	8	16	24	1	2	3
4	9	18	27	1	2	3
6	8	16	24	1	2	3
8	7	14	21	1	2	3
10	5	10	15	2	4	6
12	4	8	12	3	6	9
14	3	6	9	4	8	12
16	2	4	6	5	10	15
18	1	2	3	7	14	21
20	1	2	3	8	16	24
22	1	2	3	9	18	27
24	1	2	3	8	16	24
Total	50	100	150	50	100	150

Sample hourly rates of bulldozing, 1-man burning, and 2-man burning are shown in table 3.

Per-acre costs have been calculated for the various stands of table 2 and the costs of table 3 in the same way that the cost of the example for 2-man burning was calculated. These costs have been summarized in table 4.

Table 3. --Estimated rates[1/] for labor and equipment for bulldozing and burning

Type of operation and cost item	Rate per hour	Productive work day[2/]	Rate per productive hour
	Dollars	Percent	Dollars
BULLDOZING (100-125 drawbar hp. Hula-dozer and operator)			
Actual bulldozing time	12.00	100	12.00
Time traveling between trees	12.00	95	12.63
INDIVIDUAL TREE BURNING -- 1 MAN (Trailer-mounted tank and wheel tractor)			
Tractor operation, maintenance, and depreciation	1.25	80	1.56
Trailer, tank, torch, and hose	.20	80	.25
Propane (20.5 gal. at $0.16)[3/]	3.28	100	3.28
Labor (1 man)	1.25	80	1.56
Total actual burning time			6.65
Total time traveling between trees			3.37
INDIVIDUAL TREE BURNING -- 2 MEN (Tank in 1/2-ton pickup)			
Pickup operation, maintenance, and depreciation	1.00	80	1.25
Tank, torch, and hose	.12	80	.15
Propane (20.5 gal. at $0.16)[3/]	3.28	100	3.28
Labor (2 men)	2.25	80	2.81
Total actual burning time			7.49
Total time traveling between trees			4.21

1/ Sample rates based on 1958 custom and contract rates, and local wages and prices.

2/ Percentage of the paid working day actually spent in bulldozing or burning juniper. The rest of the time is spent in servicing and refueling, deadheading, and resting. Bulldozer charges are based on rates contracted on a moving time basis; therefore, most of the bulldozing time is productive.

3/ Amount of propane used per hour was determined from unpublished investigations by the Department of Agricultural Engineering, University of Arizona.

Table 4. --Examples of predicted per-acre costs for bulldozing and individual tree burning in hypothetical stands[1/]

Hypothetical stands	Bulldozing (100-125 drawbar hp.)			Burning -- 1 man (wheel tractor)			Burning -- 2 men (pickup)		
	Bulldozing	Travel	Total	Burning	Travel	Total	Burning	Travel	Total
	Dollars								
Predominantly small trees									
Stand 1a (50 trees)	0.94	2.73	3.67	1.39	0.58	1.97	1.57	0.34	1.91
Stand 1b (100 trees)	1.87	3.86	5.73	2.79	.82	3.61	3.14	.48	3.62
Stand 1c (150 trees)	2.81	4.71	7.52	4.18	1.00	5.18	4.71	.58	5.29
Predominantly large trees									
Stand 2a (50 trees)	2.34	2.73	5.07	3.56	.58	4.14	4.01	.34	4.35
Stand 2b (100 trees)	4.67	3.86	8.53	7.12	.82	7.94	8.02	.48	8.50
Stand 2c (150 trees)	7.01	4.71	11.72	10.68	1.00	11.68	12.03	.58	12.61

1/ Costs predicted on the basis of results given in figures 3, 4, 5, and 6; charges estimated in table 3 and stands given in table 2.

DISCUSSION AND CONCLUSIONS

Costs from 15 separate bulldozer operations and 1 burning operation were found to be within 10 percent of the costs computed by the procedure presented in this paper. This suggests that the procedure is accurate enough to guide the choice of method, provided the predicted cost difference between methods is greater than 10 percent. The causes of variation that were discussed earlier probably contribute to the spread. For example, the presence of surface rock may slow bulldozing operations. Moisture contents of the tree twigs and leaves are often higher than the maximum 70 percent found in the study, and may influence burning time. Temperatures lower than those measured during this study may make burning more difficult. Burning done during periods of very little or no wind probably will have lower costs than those predicted. Such factors should be considered in the final judgment as to choice of method.

The hypothetical juniper stands in table 2 were set up to show how size and number of trees influence costs. Cost estimates for each stand and each method, shown in table 4, indicate that burning would be cheaper than bulldozing for all small-tree stands and sparse stands of large trees. There would be no appreciable difference in cost between the two burning methods, but the 2-man crew has the advantage of having an extra man in case of an accident or in case some emergency fire-suppression action is needed. In dense stands of large trees, none of the methods considered showed a cost advantage.

Different charges for equipment and labor than those used in the examples may change the relative costs of the methods. Other methods not considered in this study may of course be cheaper than either bulldozing or individual-tree burning for certain types of stands.

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